In : Lee, Jeffrey A. and Zobeck, Ted M., 2002, Proceedings of ICAR5/GCTE-SEN Joint Conference, International Center for Arid and Semiarid Lands Studies, Texas Tech University, Lubbock, Texas, USA Publication 02-2 p. 416

Late Quaternary Eolian History of the Needles Area of Canyonlands National Park, Utah: Dunes and Dust

Marith Reheis, U.S. Geol. Survey, MS-980 Federal Center, Denver, CO 80225 (mreheis@usgs.gov)

Richard Reynolds, U.S. Geol. Survey, MS-980 Federal Center, Denver, CO 80225 (rreynolds@usgs.gov)

James Yount, U.S. Geol. Survey, MS-980 Federal Center, Denver, CO 80225 (jyount@usgs.gov)

Helen Roberts, Luminescence Laboratory, Institute of Geography and Earth Sciences, University of Wales, Aberystwyth SY23 3DB, Wales, U.K. (hmr@aber.ac.uk)

Harland Goldstein, U.S. Geol. Survey, MS-980 Federal Center, Denver, CO 80225 (hgoldstein@usgs.gov)

Yarrow Axford, National Snow and Ice Data Center, University of Colorado, Boulder, CO 80309 (axford@nsidc.org)

Nancy Shearin, Bureau of Land Management, PO Box 7, Monticello, UT 84535 (nshearin@ut.blm.gov)

Introduction and Methods

In southern Canyonlands National Park (CNP), Utah, layers of locally derived eolian sand are separated by paleosols containing eolian dust. These deposits record cyclic, late Quaternary changes in land-surface stability. Eolian dust in soils and surficial deposits strongly influences landscape evolution and ecosystem dynamics of drylands. We are applying mineralogic, chemical, textural, biologic, monitoring, and dating studies to soils and surficial deposits of the semi-arid Colorado Plateau to (1) recognize eolian dust, (2) identify past and modern dust sources, (3) study the geomorphic history, (4) document the contribution of dust to nutrient uptake by plants, and (5) assess land-surface vulnerability to wind erosion in response to changes in climate and land use. Here, we present preliminary data on the depositional history, age, and paleoclimatic setting of eolian deposits in the Needles district of CNP.

Eolian sand is locally active in the CNP area, mainly in settings with an abundant sand supply and where stabilizing vegetation has been disturbed. An older depositional record is preserved in small relict dune fields and where sand has accumulated against topographic obstructions. Within the Park, studies were limited to hand-augered holes supplemented by arroyo cuts and by two hand-dug soil pits in a dune crest and a dune swale. Additional information was obtained from backhoe pits excavated in support of an archaeological investigation just outside the boundary of CNP (Shearin et al., 2000). Optically stimulated luminescence (OSL) ages were obtained using the single-aliquot regenerative-dose (SAR) technique for both the coarse-grained (90-125 μm) and fine-grained (4-11 μm) quartz fractions of several sand layers exposed in pits and arroyo cuts. Two different grain sizes were analyzed to test whether silt was deposited together with the dune sand or was infiltrated later as dust. In addition, one radiocarbon age was obtained on charcoal at the base of an alluvial deposit that truncated a paleosol formed on eolian sand. Palynological analyses were conducted on six sediment samples from the soil pit in the dune swale.

Results and Discussion

Stratigraphy and Ages

The main study area, located in the Grabens area of CNP, consists primarily of subdued, vegetated dune ridges and swales with a maximum relief of about 5 m. Auger holes showed that the sand mantle is at least 4 m thick in the middle of the area, thinning to a few cm at the edges where it overlies sandstone bedrock. All of the auger holes exposed multiple sequences of eolian sand separated by poorly to moderately developed, silt- and carbonate-enriched soils that formed in the sand layers (Fig. 1). Each soil probably reflects a few thousand years of surface stability during which erosion, weathering, and additions of eolian dust modified the dune surfaces in a setting similar to that of the present day.

Soil pits in a dune crest (VP-1) and a swale (VP-2) provide more detailed information on the near-surface soils and sediments (Fig. 1). Data from these pits combined with auger-hole data suggest that the upper 40-50 cm represent a modern soil forming in eolian sand that overlies a better-developed soil (consistently represented by a silty textural B horizon). The contact between these two soils is not an obvious unconformity, but is clearly indicated by trends in particle size and magnetic susceptibility. These relations suggest that a former stable land surface represented by the textural B horizon has been buried by a thin, relatively young sand; soil formation has partially blended or “welded” the two soils.

The coarse-grained quartz OSL ages of eolian sand units indicate three episodes of eolian activity (Fig. 1). Ages of 8.6 and 3.7 ka were obtained for the uppermost thin sand and ages of 13.1 and 7.2 ka for the first buried sand. The older ages for the two units were obtained on samples from the dune-crest pit, whereas the younger ages were from the dune-swale pit. We are uncertain whether the differing ages represent long spans of time (4,000-5,000 years) when the dunes were active, or whether the younger ages in the swale site reflect colluvial reworking of sediment derived from the dune crests (more likely). An OSL age of ~41 ka, obtained on a truncated dune sand exposed in an arroyo cut (site 8U-14), indicates an earlier period of eolian activity. Charcoal at the base of the alluvium overlying the dune sand gave a calibrated ^{14}C age of ~5.3 ka. The alluvium gave OSL ages of ~12 ka for the coarse-grained quartz and ~8 ka for the fine-grained quartz. This age difference, with apparently older alluvium overlying younger charcoal, is probably caused by alluvial reworking of sediment from older dune sand.

The fine-grained quartz fraction of the dune sand yielded consistently younger OSL ages than the coarse-grained quartz (Fig. 1). Both coarse- and fine-grained OSL ages were of high precision, with analytical uncertainties of $\leq$ 5 %. Although these ages (with one exception), were indistinguishable within 1 or 2 σ analytical uncertainty, the slightly younger fine-grained ages may result from younger silt infiltrating the dune sands when they stabilized.

One deep arroyo cut exposes over 4 m of graben-fill deposits consisting of a thin cap of eolian sand overlying alluvial sand and pebbly sand (9U-21, Fig. 1). Three episodes of alluvial deposition are defined by three buried soils. The uppermost eolian sand is similar in character and degree of soil development to the modern soil and thin eolian sand in the nearby dune field; the youngest buried soil, formed in alluvium, is also similar to the youngest buried soil in the nearby dune field. Deposits at the base of the second alluvial unit gave very similar OSL ages (within 1 σ analytical uncertainty) of about 26 ka for the coarse- and fine-grained quartz.

At an archaeological site outside of CNP, stratigraphic relations among thin eolian sand units and paleosols (Shearin et al., 2000) suggest a geomorphic history similar to that of the main study area. These pits exposed two thin sheet sands overlying a buried soil formed on weathered bedrock, locally admixed with older eolian sand. The uppermost sheet sand is very young and in part historic based on the presence of a piece of glass at the base of the sand. A buried soil formed in the underlying sheet sand is weakly developed and similar in character to the surface soil in the main study area. The eroded paleosol formed on the underlying bedrock is moderately developed and has properties similar to those of the youngest buried soil in the dune field. A similar paleosol formed in alluvium was encountered beneath 145 cm of slopewash deposits deposited in a nearby small drainage.

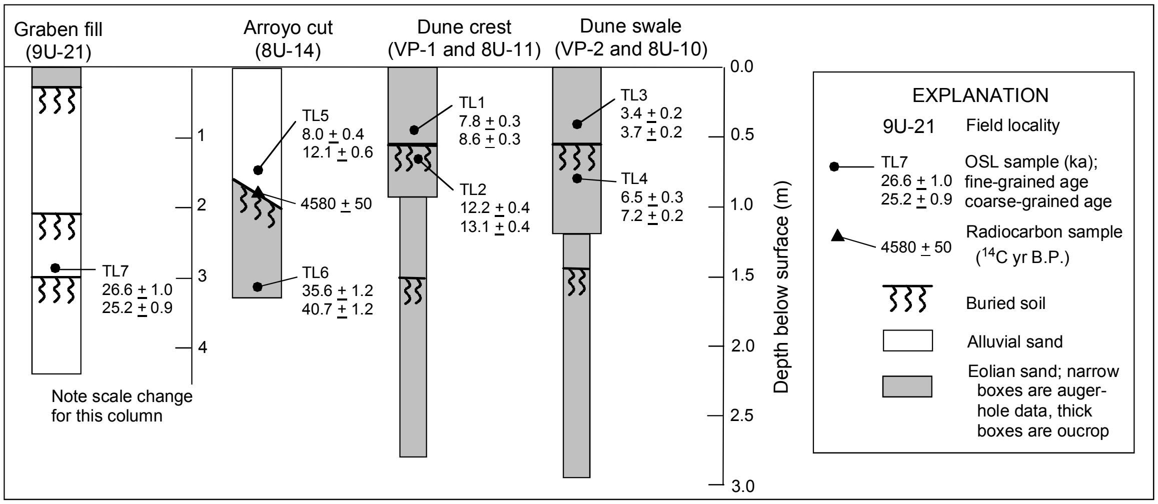

Figure 1. Stratigraphy and ages of dune sand and alluvium in study area from selected auger holes and outcrops.

Paleoclimate Data

Pollen abundances in samples from the dune-swale pit suggest significant climate changes over the period of deposition. The lowermost sample (110-115 cm depth, or 20-25 cm below the coarse-grained OSL age of 7.2 ka) contains abundant grass and common arboreal pollen (13 %; Pinus and Juniperus,) and Artemisia (11 %). The middle part of the record, between about 45-95 cm depth, is characterized by very high Cheno-Am percentages, and sparse (<5 %) to absent arboreal pollen. The lowest arboreal pollen percentages and lowest Artemisia:Cheno-Am ratio (an indicator of summer precipitation, e.g., Shafer, 1989) are both coincident with the base of the surface soil, just below the coarse-grained OSL age of 3.7 ka. These data suggest that a Cheno-Am-rich flora reflecting aridity accompanied landscape destabilization and renewed eolian or slopewash deposition at this site. Most notably, Pinus and Juniperus expand greatly between 14 cm depth and the surface, accompanied by a doubling of the Artemisia:Cheno-Am ratio. The presence of a probable Tamarix (tamarisk) grain in the Bw horizon (5-14 cm) indicates that the uppermost sediments in the dune swale are less than 100 yr old.

These pollen data are consistent with pollen analyses from the archaeological site (Shearin et al., 2000). Here, the buried soil formed in sand and weathered bedrock as well as the soil buried beneath the slopewash contained relatively abundant Artemisia, grass, and arboreal pollen, whereas the soil formed on the pre-modern sand sheet and the slopewash deposits contained little Artemisia, grass, and arboreal pollen and abundant Cheno-Am pollen. Taken together, the two sets of pollen analyses and the OSL ages suggest a relatively wet period in the study area before 7-8 ka and drought during the middle to late Holocene, between about 7 and 3 ka.

Conclusions

The stratigraphy and ages of deposits in the dune field and associated alluvium combined with pollen data suggest these preliminary interpretations: (1) An episode of eolian activity at about 40 ka. (2) A wetter or more stormy period that produced alluvial deposition (graben fill) from some time prior to about 25 ka until before about 13 ka. (3) A second period of eolian deposition around 13 ka in the dune field. (4) A wetter period around 10 ka, during which soils formed relatively quickly by infiltration of eolian silt and clay, and trees and grass were common on the landscape. (5) A dry and perhaps stormy period between about 9-8 ka and 4-3 ka, during which some parts of the dune field were reactivated, slope wash accumulated, alluvial erosion and deposition occurred, and more desert-like vegetation was dominant. (6) Increasing moisture after about 3 ka, during which dunes stabilized and trees and grass reoccupied favorable settings.

These paleoclimatic interpretations are consistent with conclusions from previous studies of pollen and packrat middens on the Colorado Plateau. The closest locality to the study area that lies at a similar altitude is Cowboy Cave, west of the study area. The record from this cave indicates increased moisture from an enhanced monsoon from about 13.5 to 8.9 ka, followed by inception of more xeric conditions (Spaulding and Peterson, 1980, cited in Shafer, 1989). The ratio of Artemisia to Cheno-Am pollen increased sharply during the enhanced monsoon period. The period of mid-Holocene aridity apparently ended with a rise in effective precipitation some time between 4 and 2 ka (e.g., Sharpe, 1991; Weng and Jackson, 1999).

References

Shafer, D.S. 1989. The timing of late Quaternary monsoon precipitation maxima in the southwest United States. Unpublished Ph.D. dissertation, Tucson, University of Arizona, 234 p.

Sharpe, S. 1991. Late-Pleistocene and Holocene vegetation change in Arches National Park, Grand County, Utah and Dinosaur National Monument, Moffat County, Colorado. Unpublished Masters thesis, Northern Arizona University, Flagstaff, AZ.

Shearin, N., M.C. Reheis, and L.S. Cummings. 2000. 42SA23136 Test Report and Analysis Results, Hamburger Rock Campground. U.S. Department of the Interior, Bureau of Land Management, Monticello, Utah, 39 p.

Weng, C. and S.T. Jackson. 1999. Late glacial and Holocene vegetation history and paleoclimate of the Kaibab Plateau, Arizona. Palaeogeography Palaeoclimatology Palaeoecology 153:179-201.